STORAGE CONDITIONS
FRUITS & VEGETABLES

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Once a crop is harvested, it is almost impossible to improve its quality. Losses of horticultural crops due to improper storage and handling can range from 10 to 40 percent. Proper storage conditions—*temperature and humidity*—are needed to lengthen storage life and maintain quality once the crop has been cooled to the optimum storage temperature.

Fresh fruits and vegetables are living tissues, although they are no longer attached to the plant. They breathe, just as humans do, and their composition and physiology continue to change after harvest. They continue to ripen and, finally, they begin to die. Cellular breakdown and death (senescence) are inevitable, but can be slowed with optimal storage conditions. Fresh fruits and vegetables need low temperatures (32 to 55°F) and high relative humidities (80 to 95 percent) to lower respiration and to slow metabolic and transpiration rates. By slowing these processes, water loss is reduced and food value, quality and energy reserves are maintained.

Relative Humidity

Transpiration rates (water loss from produce) are determined by the moisture content of the air, which is usually expressed as relative humidity. At high relative humidity, produce maintains salable weight, appearance, nutritional quality and flavor, while wilting, softening and juiciness are reduced. Leafy vegetables with high surface-to-volume ratios; injured produce; and immature fruits and vegetables have higher transpiration rates. External factors affecting transpiration rates are temperature, relative humidity, air velocity and atmospheric pressure. High temperatures, low relative humidity and high air velocity increase transpiration rates.

Relative humidity needs to be monitored and controlled in storage. A hygrometer or a sling psychrometer, not the appearance of the produce, should be used to monitor humidity. Control can be achieved by a variety of methods:

1. Operating a humidifier in the storage area.
2. Regulating air movement and ventilation in relation to storage room load.
3. Maintaining refrigeration coil temperature within 2°F of the storage room air temperature.
4. Using moisture barriers in the insulation of the storage room or transport vehicle, and in the lining of the packing containers.
5. Wetting the storage room floor.
6. Using crushed ice to pack produce for shipment.
7. Sprinkling leafy vegetables, cool-season root vegetables, and immature fruits and vegetables with water.

Table 1 lists the optimum relative humidity for the storage of several fruits and vegetables.

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Temperature

Respiration and metabolic rates are directly related to room temperatures within a given range. The higher the rate of respiration, the faster the produce deteriorates. Lower temperatures slow respiration rates and the ripening and senescence processes, which prolongs the storage life of fruits and vegetables. Low temperatures also slow the growth of pathogenic fungi which cause spoilage of fruits and vegetables in storage. Table 2 contains a list of fruits and vegetables classified by respiration rates. Producers should give special care and attention to proper storage conditions for produce with high to extremely high respiration rates—those crops will deteriorate much more quickly.

It is impossible to make a single recommendation for cool storage of all fruits and vegetables. Climate of the area where the crop originated, the plant part, the season of harvest and crop maturity at harvest are important factors in determining the optimum temperature. A general rule for vegetables is that cool-season crops should be stored at cooler temperatures (32 to 35°F), and warm-season crops should be stored at warmer temperatures (45 to 55°F). There are exceptions to this rule, though. Table 1 lists optimum storage temperatures for commonly grown Kansas fruits and vegetables.

Freezing Injury. Temperatures that are too low can be just as damaging as those too high. Freezing will occur in all commodities below 32°F. Whether injury occurs depends on the commodity. Some can be repeatedly frozen and thawed without damage, while others are ruined by one freezing. Table 1 shows the highest freezing point for most fruits and vegetables. Table 3 lists susceptibility to freezing injury. Produce that is likely to be injured by one freezing is classified as “most susceptible.” The “moderately susceptible” produce will recover from one or two freezings. Produce which is “least susceptible” can survive several freezings without injury.

Injury from freezing temperatures can appear in plant tissues as loss of rigidity, softening and water soaking. Injury can be reduced if the produce is allowed to warm up slowly to optimum storage temperatures, and if it is not handled during the thawing period. Injured produce should be marketed immediately, as freezing shortens its storage life.

Chilling Injury. Fruits and vegetables that require warmer storage temperatures (40 to 55°F) can be damaged if they are subjected to near-freezing temperatures (32°F). Cooler temperatures interfere with normal metabolic processes. Injury symptoms are varied and often do not develop until the produce has been returned to warmer temperatures for several days. Besides physical damage, chilled produce is often more susceptible to disease infection. Table 4 lists susceptible fruits and vegetables, and characteristic symptoms of chilling injury.

Storage Facilities

Crops that require different storage conditions will need three different storage facilities.

Cold storage (temperatures 32 to 36°F).

Cool storage (temperatures 40 to 55°F).

Warmer storage (temperatures 55 to 60°F for sweet potatoes, squash, pumpkins or similar crops).

A recording thermometer can be helpful in determining whether storage facilities are maintaining ideal conditions and are not fluctuating. A maximum / minimum thermometer could be substituted. The thermometer should not be the same as the thermostat controlling the refrigeration equipment. Relative humidity also should be monitored with a hygrometer or a sling psychrometer.

Controlling and monitoring temperature and relative humidity will enable a grower to maintain optimum conditions for maximum storage life of the crop, and to minimize crop damage from chilling, freezing and / or too-high temperatures and water loss from the crop. Close attention to storage conditions will yield returns through greater customer satisfaction, less waste and spoilage, and in the flexibility to hold a crop without significant storage losses to wait for better markets.

References

Hardenburg, R.E., A.E. Watada and C.Y. Wang. 1986. *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.* USDA-ARS Agriculture Handbook Number 66 (revised) 136p.

Table 1. Commonly grown fruits and vegetables with recommended storage conditions for temperature and relative humidity, approximate storage life under optimum conditions and highest freezing points.

Commodity	Temperature (°F)	Rel. humidity (percent)	Approximate storage life	Freezing point (°F)
FRUITS				
Apples	30–40	90–95	1–12 months	29.3
Apricots	31–32	90–95	1–3 weeks	30.1
Berries				
Blackberries	31–32	90–95	2–3 days	30.5
Currants	31–32	90–95	1–4 weeks	30.2
Elderberries	31–32	90–95	1–2 weeks	—
Gooseberries	31–32	90–95	3–4 weeks	30.0
Raspberries	31–32	90–95	2–3 days	30.0
Strawberries	32	90–95	3–7 days	30.6
Cherries, sour	32	90–95	3–7 days	29.0
Cherries, sweet	30–31	90–95	2–3 weeks	28.8
Grapes, American	31–32	85	2–8 weeks	29.7
Nectarines	31–32	90–95	2–4 weeks	30.4
Peaches	31–32	90–95	2–4 weeks	30.3
Pears	29–31	90–95	2–7 months	29.2
Plums and prunes	31–32	90–95	2–5 weeks	30.5
Quinces	31–32	90	2–3 months	28.4
VEGETABLES				
Artichokes, Jerusalem	31–32	90–95	4–5 months	28.0
Asparagus	32–35	95–100	2–3 weeks	30.9
Beans, dry	40–50	40–50	6–10 months	—
Beans, green or snap	40–45	95	7–10 days	30.7
Beans, lima	37–41	95	5–7 days	31.0
Beans, sprouts	32	95–100	7–9 days	—
Beets, bunched	32	98–100	10–14 days	31.3
Beets, topped	32	98–100	4–6 months	30.3
Broccoli	32	95–100	10–14 days	30.9
Brussels sprouts	32	95–100	3–5 weeks	30.5

Commodity	Temperature (°F)	Rel. humidity (percent)	Approximate storage life	Freezing point (°F)
Cabbage, early	32	98–100	3–6 weeks	30.4
Cabbage, late	32	98–100	5–6 months	30.4
Cabbage, Chinese	32	95–100	2–3 months	—
Carrots, bunched	32	95–100	2 weeks	—
Carrots, mature	32	98–100	7–9 months	29.5
Carrots, immature	32	98–100	4–6 weeks	29.5
Cauliflower	32	95–98	3–4 weeks	30.6
Celeriac	32	97–99	6–8 months	30.3
Celery	32	98–100	2–3 months	31.1
Chard	32	95–100	10–14 days	—
Chicory, witloof	32	95–100	2–4 weeks	—
Collards	32	95–100	10–14 days	30.6
Corn, sweet	32	95–98	5–8 days	30.9
Cucumbers	50–55	95	10–14 days	31.1
Eggplant	46–54	90–95	1 week	30.6
Endive and escarole	32	95–100	2–3 weeks	31.9
Garlic	32	65–70	6–7 months	30.5
Greens, leafy	32	95–100	10–14 days	—
Horseradish	30–32	98–100	10–12 months	28.7
Jicama	55–65	65–70	1–2 months	—
Kale	32	95–100	2–3 weeks	31.1
Kohlrabi	32	98–100	2–3 months	30.2
Leeks	32	95–100	2–3 months	30.7
Lettuce	32	98–100	2–3 weeks	31.7
Melons				
Cantaloupe (3/4 slip)	36–41	95	15 days	29.9
Cantaloupe (full slip)	32–36	95	5–14 days	29.9
Casaba	50	90–95	3 weeks	30.1
Crenshaw	45	90–95	2 weeks	30.1
Honey Dew	45	90–95	3 weeks	30.3
Persian	45	90–95	2 weeks	30.5
Watermelon	50–60	90	2–3 weeks	31.3

Commodity	Temperature (°F)	Rel. humidity (percent)	Approximate storage life	Freezing point (°F)
Mushrooms	32	95	3–4 days	30.4
Okra	45–50	90–95	7–10 days	28.7
Onions, green	32	95–100	3–4 weeks	30.4
Onion, dry	32	65–70	1–8 months	30.6
Onion sets	32	65–70	6–8 months	30.6
Parsley	32	95–100	2–2.5 months	30.0
Parsnips	32	98–100	4–6 months	30.4
Peas, green	32	95–98	1–2 weeks	30.9
Peas, southern	40–41	95	6–8 days	—
Peppers, chili (dry)	32–50	60–70	6 months	—
Peppers, sweet	45–55	90–95	2–3 weeks	30.7
Potatoes, early crop	40	90–95	4–5 months	30.9
Potatoes, late crop	38–40	90–95	5–10 months	30.9
Pumpkins	50–55	50–70	2–3 months	30.5
Radishes, spring	32	95–100	3–4 weeks	30.7
Radishes, winter	32	95–100	2–4 months	—
Rhubarb	32	95–100	2–4 weeks	30.3
Rutabagas	32	98–100	4–6 months	30.0
Salsify	32	95–98	2–4 months	30.0
Spinach	32	95–100	10–14 days	31.5
Squashes, summer	41–50	95	1–2 weeks	31.1
Squashes, winter	50	50–70	1–6 months	30.5
Sweet potatoes	55–60	85–90	4–7 months	29.7
Tomatoes, mature—green	55–70	90–95	1–3 weeks	31.0
Tomatoes, firm—ripe	55–70	90–95	4–7 days	31.1
Turnips	32	95	4–5 months	30.1
Turnip greens	32	95–100	10–14 days	31.7
Watercress	32	95–100	2–3 weeks	31.4

Table 2. Fruits and vegetables classified by their respiration rates (at 41°F).

Class	Respiration rate Btu / ton / 24 hrs	Commodity
Very low	<5	Nuts, Dates, Dried Fruits and Vegetables
Low	5–10	Apple, Grape, Garlic, Onion, Potato (mature), Sweet Potato
Moderate	10–20	Apricot, Cherry, Peach, Pear, Nectarine, Plum, Cabbage, Carrot, Lettuce, Pepper, Tomato, Potato (immature)
High	20–40	Strawberry, Blackberry, Lima Bean, Raspberry, Cauliflower
Very high	40–60	Artichoke, Snap Bean, Green Onion, Brussels Sprouts
Extremely high	>60	Asparagus, Broccoli, Sweet Corn, Mushroom, Spinach, Pea

Table 3. Fruits and vegetables classified by susceptibility to injury by temperatures below 32°F.

Group 1, Most susceptible	Group 2, Moderately susceptible	Group 3, Least susceptible
Apricots	Apples	Beets[1]
Asparagus	Broccoli, sprouting	Brussels Sprouts
Beans, snap	Cabbage, new	Cabbage, mature and savoy
Berries (except cranberries)	Carrots[1]	Kale
Cucumbers	Cauliflower	Kohlrabi
Eggplant	Celery	Parsnips
Lettuce	Cranberries	Rutabagas
Okra	Grapes	Salsify
Peaches	Onions (dry)	Turnips[1]
Peppers, sweet	Parsley	
Plums	Pears	
Potatoes	Peas	
Squash, summer	Radishes[1]	
Sweet Potatoes	Spinach	
Tomatoes	Squash, winter	

[1]Without tops

Table 4. Fruits and vegetables susceptible to chilling injury when exposed to temperatures below their optimum range and above 32˚F.

Commodity	Approx. lowest safe temperature (°F)	Symptoms of injury from below-optimum temperatures
Apples-certain cultivars	36–38	Internal browning, brown core, soggy breakdown, soft scald
Asparagus	32–36	Dull, gray-green, limp tips
Beans (lima)	34–40	Rusty brown specks, spots, or areas
Beans (snap)	45	Pitting and russeting
Cucumbers	45	Pitting, water-soaked spots, decay
Eggplants	45	Surface scald, alternaria rot, blackening of seeds
Melons		
Cantaloupe	36–41	Pitting, surface decay
Honey Dew	45–50	Reddish-tan discoloration, pitting, surface decay, failure to ripen
Casaba	45–50	Same as above, but no discoloration
Crenshaw and Persian	45–50	Same as above, but no discoloration
Watermelons	40	Pitting, objectionable flavor
Okra	45	Discoloration, water-soaked areas, pitting, decay
Peppers, sweet	45	Sheet pitting, alternaria rot on pods and calyxes, darkening of seed
Potatoes	38	Sweetening
Pumpkins and hardshell squashes	50	Decay, especially alternaria rot
Sweet Potatoes	55	Decay, pitting, internal discoloration; hard core when cooked
Tomatoes		
Ripe	45–50	Water soaking and softening decay
Mature-green	55	Poor color when ripe, alternaria rot

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